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Theordore H. Okiishi

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IOWA STATE UNIVERSITY
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Final Scientific Report

MULTISTAGE AXIAL-FLOW TURBOMACHINE WAKE PRODUCTION, TRANSPORT AND INTERACTION

Theodore H. Okiishi, Professor

February 1979

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DEPARTMENT OF MECHANICAL ENGINEERING
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INTRODUCTION

Research on multistage axial-flow turbomachine wake production, transport and interaction was pursued at Iowa State University under Air Force Office of Scientific Research sponsorship (AFOSR Grant 76-2916) with cost sharing by the ISU Engineering Research Institute and Mechanical Engineering Department from 1 September 1975 till 31 December 1978.

The general objectives of the research were:

1. To develop a better understanding of the fluid mechanics of flow through multistage, axial-flow turbomachines.
2. To assess the influence of circumferential positioning of the rows of blades in a multistage, axial-flow turbomachine on the aerodynamic performance, acoustic characteristics and aeromechanical interactions involved.
3. To improve turbomachine fluid flow measuring techniques and equipment.
4. To incorporate research results of the above mentioned objectives into turbomachine design procedures.

Specific results related to these general objectives have been obtained and reported as discussed in the next section. The research has lead to the development of some viable flow measuring techniques and the organization and classification of some important details of turbomachine unsteady flow fluid mechanics. A considerable amount of time-average and periodic-average flow velocity and pressure data have been made available.

SUMMARY OF SIGNIFICANT RESEARCH RESULTS

The detailed results of the research effort have been previously reported in a number of documents. These include several technical reports (References 1,2,3 and 4), journal articles (References 5 and 6), a conference proceedings entry (Reference 7), formal lecture notes (Reference 8) and unpublished M.S. degree theses (References 9,10,11 and 12). Additionally, two short 16 mm films were made with sequential computer drawings to illustrate periodically varying flow field (vector sheet) and wake chopping, transport and interaction occurrence in the research compressor in slow motion.

Procedures and instrumentation for acquiring time-average (slow response average of continuously sampled data) and periodic-average (electronic and arithmetic average of periodically sampled data) flow field data between blade rows of a research turbomachine were developed. Slow and fast-response total pressure probes and hot-wire anemometry were involved. A special 5μs sampling and holding circuit that could be phase locked to reference rotor blade position was designed and built. Two-dimensional time-average and three-dimensional periodic-average velocity vector information was obtained.

The observed time-average flow patterns involved appreciable circumferential variations behind rotors as well as stators and they could be changed significantly by circumferentially shifting upstream stationary blades.

The observed periodic-average flow patterns showed that rotor and stator flow fields are three-dimensional as well as periodically

unsteady. Downstream effects due to wake chopping, transport and interaction and upstream potential field effects were noted.

A simple wake chopping transport and interaction model based on experimental data proved to be an excellent means for organizing and explaining data trends. The variations of periodic-average flow patterns with rotor sampling position could be understood in terms of the wake chopping, transport and interaction model proposed.

Compressor inlet noise measurements indicated that blade-passing-frequency noise level could be changed substantially with appropriate stationary blade row circumferential positioning when the same number of blades was present in each stationary blade row and when the spinning blade interaction pattern speed was above the "cut-off" amount. Accompanying significant changes of overall compressor performance could not be detected although some local variations in deviation angles were observed. It was concluded that the noise level difference was due to sound wave interference as well as sound source (fluctuating blade-surface pressure) variation.

A considerable amount of multistage research compressor data has been organized and tabulated for future use. This collection of data should be useful for checking proposed flow calculation methods as well as for acquiring further understanding of multistage turbomachine flow fluid mechanics.

The results of related research by others have been studied and compared with those obtained at Iowa State and a comprehensive review

statement which includes some ways in which the present results may be useful to designers has been developed.

REFERENCES

1. Schmidt, D. P. and Okiishi, T. H., "Multistage Axial-Flow Turbomachine Wake Production, Transport, and Interaction," Iowa State University Engineering Research Institute Interim Report TCRL-7, ISU-ERI-AMES-77130, 1976.

2. Wagner, J. H. and Okiishi, T. H., "Analysis of Multistage, Axial-Flow Turbomachine Wake Production, Transport, and Interaction," Iowa State University Engineering Research Institute Technical Report TCRL-10, ISU-ERI-AMES-78173, 1977.

3. Alarcon, G. A., Okiishi, T. H. and Junkhan, G. H., "Design and Application of a Fast Response Total Pressure Probe for Turbomachinery Flow Measurement," Iowa State University Engineering Research Institute Technical Report TCRL-9, ISU-ERI-AMES-78205, December 1977.

4. Holbrook, G. J. and Okiishi, T. H., "The Influence of Compressor Inlet Guide Vane / Stator Relative Circumferential Positioning on Wake Transport and Interaction," Iowa State University Engineering Research Institute Technical Report TCRL-13, ISU-ERI-AMES-79037, 1978.

5. Schmidt, D. P. and Okiishi, T. H., "Multistage Axial-Flow Turbomachine Wake Production, Transport, and Interaction," AIAA Journal 15:1138-1145, 1977.

6. Wagner, J. H., Okiishi, T. H. and Holbrook, G. J., "Periodically Unsteady Flow in an Imbedded Stage of a Multistage Axial-Flow Turbomachine," ASME Transactions Journal of Engineering for Power 101:42-51, 1979.

7. Okiishi, T. H. and Schmidt, D. P., "Measurement of the Periodic Variation of Turbomachine Flow Fields," Proceedings of the Dynamic Flow Conference 1978: 249-269, 1979.

8. Okiishi, T. H., "Turbomachine Wake Transport and Interaction Effects," In von Karman Institute for Fluid Dynamics Lectures Series on "Unsteady Flow in Turbomachines," 1979.

9. Schmidt, D. P., "Detailed Measurements of the Periodically Unsteady Flow Produced by Rotor and Stator Wake Interaction in a Multistage Axial-Flow Turbomachine," Unpublished M.S. thesis, Iowa State University, Ames, Iowa, 1976.

10. Wagner, J. H., "Analysis of Multistage, Axial-Flow Turbomachine Wake Production, Transport, and Interaction," Unpublished M.S. thesis, Iowa State University, Ames, Iowa, 1977.

11. Alarcon, G. A., "Design and Application of a Fast-Response Total-Pressure Probe for Turbomachinery Flow Measurement," Unpublished M.S. thesis, Iowa State University, Ames, Iowa, 1977.

12. Holbrook, G. J., "The Influence of Stator Row Circumferential Positioning on Wake Transport and Interaction in a Multistage Axial-Flow Turbomachine," Unpublished M.S. thesis, Iowa State University, Ames, Iowa, 1978.